STREAM HABITAT RESTORATION GUIDELINES
CHAPTER 5

DESIGNING AND IMPLEMENTING STREAM HABITAT RESTORATION TECHNIQUES

Chapter 5 is a compilation of techniques that are commonly applied to restore, rehabilitate, enhance, or create stream habitat. The information presented in these techniques is intended to assist landowners, land managers, and other stream restoration practitioners in developing designs and implementing various components of stream habitat restoration projects. It is recommended that before proceeding to this chapter, the restoration practitioner should have already completed a site, reach, or watershed assessment (Chapter 3, *Stream Habitat Assessment*), as appropriate, to determine limiting factors to ecosystem recovery and to identify restoration opportunities and constraints. They should also have identified realistic restoration goals and objectives and developed a restoration strategy to meet those goals and objectives (Chapter 4, *Developing a Restoration Strategy*). In addition to the techniques presented in this chapter, appendices to this document and related Aquatic Habitat Guidelines white papers (http://wdfw.wa.gov/hab/ahg/ahgwhite.htm) provide detailed information on specific methods of analysis, additional sources of information, and general background on related sciences and other components of project planning, design, and implementation.

The intent of the following techniques is not to provide a “cookbook” that walks you through every analysis that may be required. The reason for this is that design of many of the techniques described herein generally requires substantial input from an interdisciplinary team. Attempting to serve as a complete resource for practitioners with varying levels of knowledge of each discipline would be a daunting task both for the readers and the authors. Additionally, many projects will require site-specific and project-specific criteria to meet varying interests, objectives, and constraints. As such, the following techniques focus on providing readers with a comprehensive list of factors to consider when planning, designing, and constructing stream restoration work. Design criteria are suggested and, when appropriate, references for additional design guidance are provided.

The techniques present what the authors consider to be the best available science for each method. The information provided represents the integration of that available through other guidelines and the literature, as well as the experience of the authors and contributors to this document.

5.1 Techniques Included in this Guideline

The optimal goal of stream habitat restoration is to restore the natural processes that create, maintain, and connect stream habitat, including sediment transport, scour, deposition, channel migration, riparian development, nutrient cycling, flooding, etc. However, some of the techniques presented below do not work towards that goal. They are nonetheless included because they have other utility in their application, particularly in situations where true restoration of channel processes may be impossible given political, social, and physical land use constraints, such as those found in highly urbanized stream systems.

Techniques detailed in these guidelines include:

1. Dedicating Land and Water to the Preservation and Restoration of Stream Habitat
2. Channel Modification
3. Levee Modification and Removal
4. Side Channel / Off-Channel Habitat Restoration
5. Riparian Restoration and Management
6. Fish Passage Restoration
7. Nutrient Supplementation
8. Beaver Re-introduction
9. Salmonid Spawning Gravel Cleaning and Placement
10. Instream Structures
    a. General Design and Selection Considerations for Instream Structures
    b. Boulder Clusters
    c. Large Wood and Log Jams
    d. Drop Structures
    e. Porous Weirs
11. Bank Protection Construction, Modification, and Removal
12. Instream Sediment Detention Basins

The collection of techniques presented herein is not a comprehensive list of all stream habitat restoration, rehabilitation, enhancement, and creation techniques, nor is it intended to limit the designer. It does not include:

- A wide range of watershed management techniques, including Best Management Practices, that address point and non-point source pollution, slope stability, and changes in sediment supply, large wood supply, and flow regime, many of which may be necessary to address the root cause of habitat degradation as outlined in Chapter 4.5, *Approaches to Achieving Common Restoration Goals*.
- Many techniques that treat the symptoms of habitat degradation, rather than the cause, and whose detrimental impacts to the ecosystem typically outweigh any benefits that they provide. For instance, dredging a stream channel that has aggraded due to an increase in sediment delivery to the stream from a denuded watershed may increase the depth of flow and prevent fish stranding within the floodplain. But it provides only a short-term solution unless the cause of increased sediment delivery is addressed. It is also very disruptive to existing habitat, it may sever the connection between the channel and its floodplain and riparian habitats, and it may cause upstream and downstream channel incision. Some techniques that address only the symptoms of habitat degradation (e.g., instream sediment detention, gravel cleaning, bank stabilization) are included here because they are in common use and they have some application to stream habitat restoration under limited circumstances or when used in conjunction with other techniques.
- Techniques that have been used in the past that have not been successful, or which inhibit or impede natural habitat-forming processes. This includes any form of hardening of the channel or banks that will ultimately restrict the channel's ability to adjust to changing

inputs.

- Techniques that may be appropriate but whose utility has not been demonstrated to date or is not known to the authors at this time.
- Land use planning and establishment of protective regulations that is critical to the long-term success of restoration.
- Wetland restoration
- Estuary Restoration (topic of a proposed future Washington State guideline)

5.2 Information Included Within Each Technique

Each technique in this guideline includes the following information:

1. *Description*: A general explanation of the technique.
2. *Physical and Biological Effects*: A discussion of the potential benefits and impacts resulting from implementation of the technique.
3. *Application*: When, where, and why to use the technique, and under what conditions it may be appropriate or inappropriate.
4. *Risk and Uncertainty*: A discussion of the risk to habitat, to infrastructure and property, and to public safety, and of the uncertainty in application of the technique.
5. *Methods and Design*: How to design a project using the selected technique, including data to collect, analyses to conduct, variations and methods of application, and references to additional resources for design guidance.
6. *Permitting*: Permits that are typically required to implement the technique. A more thorough discussion of permitting considerations is presented in the *Typical Permits Required for Work In and Around Water* appendix.
7. *Construction Considerations*: Aspects of the technique that may require special consideration with regards to construction. A more thorough discussion of construction considerations that are common to all or most techniques is provided in the *Construction Considerations* appendix.
8. *Cost*: A typical range of costs for materials and construction and the elements that affect cost variability. The cost of materials, hauling distances, and site access can differ dramatically among projects and can overwhelm typical project costs.
9. *Monitoring*: Special considerations for monitoring that are not otherwise presented in the *Monitoring Considerations* appendix.
10. *Maintenance*: Short and long-term maintenance requirements.
11. *Examples*: Descriptions and photos of example projects using each technique are presented. Conceptual drawings are also provided.

The cost of design for habitat restoration projects generally ranges from 15 to 50 % of implementation costs. This may be higher than that for traditional civil engineering works. The reason for this is that 1) the same analysis is generally necessary whether the project is large or small so the percentage of implementation cost will be larger for smaller projects, and 2) habitat restoration projects are very site specific and it is generally not possible to apply designs used on previous projects to new ones.

5.3 Design of Techniques

Once the tasks or techniques necessary to achieve overall restoration goals and objectives have been identified and prioritized, planning and design of individual projects can begin. The process involved is similar to that outlined for developing a restoration strategy in Chapter 4 of this guideline. It typically includes the following steps:

1. Identify stakeholders and interests (discussed below in this introduction)
2. Identify project constraints (discussed below in this introduction)
3. Define project goals and objectives
4. Develop design criteria to meet those goals and objectives (discussed below in this introduction)
5. Collect data and conduct necessary assessments and baseline monitoring (discussed in each technique)
6. Evaluate the risks to the environment, infrastructure, property, and public safety that are associated with both project installation and failure (risks are described for each technique)
7. Develop project designs (design components and methods are presented for each technique)
8. Develop a construction plan (refer to the *Construction Considerations* appendix)
9. Develop drawings, specifications, and contracting documents (example drawings are provided for most techniques)
10. Construct the project
11. Conduct post-construction monitoring (monitoring considerations are discussed briefly in each technique and in greater detail in the *Monitoring Considerations* appendix)

5.3.1 Expertise Required

Restoration, rehabilitation, enhancement, or creation of natural stream channels and habitat is a relatively young and developing science. Techniques are numerous, and many are unproven. In addition to often-complicated social and political considerations, the ecological and physical complexity of stream systems requires an understanding and appreciation of many disciplines within the natural sciences and engineering. As such, it is commonly the subject of debate among academics and practitioners from many disciplines and organizations. Early phases of project planning, including identification of project objectives and alternatives analysis, will benefit from an interdisciplinary approach and may require expertise from several related scientific and engineering disciplines, including:

- Hydrology. Hydrologists determine the impact of watershed change on the hydrologic regime and can help identify causes related to hydrologic impacts, and evaluate alternatives with respect to altered hydrologic regimes.
- Geology and fluvial geomorphology. Geologists can identify geologic inputs and controls to the channel, such as sediment sources and natural grade control. Geomorphologists evaluate the stability and form of the stream channel and the inputs and processes that control them.
- Fish biology and aquatic ecology, including aquatic entomology. Aquatic life scientists are essential to evaluating habitat condition, conducting population studies, and limiting factors analyses.
- Botany and plant ecology. Plant ecologists and botanists evaluate riparian condition, which determines the availability and quality of riparian habitat and influences channel stability, habitat structure, available energy, water quality, and hydrologic variables.

They are also crucial to the development of achievable riparian restoration objectives, methods, designs, and management.

- Wildlife and conservation biology. Wildlife biologists provide information and analysis of terrestrial, amphibian, and avian species that depend on and influence stream and riparian habitat.
- Landscape Ecology. Landscape ecologists compile and evaluate broad-scale ecological and land use data using remote sensing, GIS, and other technology. Such data is useful to determine the extent and distribution of habitats and problems within a watershed or ecosystem, to identify likely causes to those problems and threats to habitat, and to make recommendations to preserve, restore, and enhance habitat.
- Engineering. The evaluation and design of restoration, rehabilitation, and other stream habitat projects often relies on analysis, modeling, and assessment provided by professional engineers with expertise in hydraulics, civil, environmental, sediment transport, and geotechnical engineering.
- Construction. Individuals familiar with construction are skilled at evaluating access availability, equipment requirements, and construction feasibility.

5.3.2 Identify Stakeholders and Interests

Successful restoration requires involvement from numerous stakeholders early in the process of planning a restoration project. Stakeholders may include:

- State and federal resource agencies,
- Local government,
- Landowners,
- Tribes,
- Community and related businesses,
- Hunters, anglers and other recreationists, and
- Environmental advocacy organizations.

Inclusion of all impacted, interested, and involved parties will help develop project objectives that are achievable. Each stakeholder brings to the table their own set of objectives, some of which may benefit fish and wildlife while others may not. Early stakeholder involvement and the negotiation among them will provide the designer with an opportunity to address all concerns and to maximize benefits to fish and wildlife in a cost-effective timely manner. It may also yield a project that addresses multiple objectives and provides opportunities to further expand restoration work. Early involvement provides each stakeholder with a sense of ownership that helps to bolster community support and encourages donations of money, materials, and services to design, construct, monitor, and maintain the project. The longer stakeholder involvement is delayed, the more likely the project will be rejected and design modifications will be required to proceed.

5.3.3 Identify Project Constraints

There are many possible societal, political, and logistical project constraints to address. The myriad of stakeholders contributing to the development of project objectives will facilitate the identification of potential hurdles and roadblocks in the path to implementation. The earlier these roadblocks are identified, the earlier they can be addressed. Project implementation may be limited by:

- Permitting. Numerous federal, state, and local permits may be required to implement a project, even though the goal is to restore stream habitat. Permits sometimes take years to obtain, especially if endangered species may be positively or negatively impacted by the project. Permit requirements may sometimes conflict, causing further delays while these conflicts are resolved. See the *Typical Permits Required for Work In or Around Water* appendix for more information on permitting.
- Regulatory authority. When a number of regulatory entities are involved, the degree of authority of each agency is sometimes unclear. Delays in project development or implementation may result, especially if restoration priorities and recommendations conflict among agencies.
- Resistant stakeholders. Unwilling stakeholders may prevent any project from proceeding or limit the extent of the project such that certain restoration objectives cannot be met.
- Funding. Project funding may be insufficient to cover the design, implementation, maintenance and monitoring costs. Funding may also have sunset dates or only be available for specific types of work.
- Resource management policy. Current management policies and protocols may conflict with restoration goals.
- Infrastructure. Existing infrastructure may limit the spatial extent of treatment such that certain restoration objectives cannot be met.
- Private landowner concerns. Private landowners often pose significant restrictions on activities on their property, and their land management preferences may be inconsistent with restoration goals.
- Time. There may not be sufficient time for the project to work through the development steps needed to achieve implementation to meet the criteria of funding, availability of key personnel, scheduled development activities or other limitations.

While significant constraints to restoration opportunities may exist, stakeholders should consider whether these constraints are perceived or absolute, and if they can be overcome through negotiation, mitigation, procurement of additional funding, or development of additional alternatives. Stakeholders should consider whether these constraints allow the project to restore habitat or whether they limit it to enhancement only. Where limitations to complete restoration exist, there may be alternative rehabilitation or enhancement projects that can meet many stakeholder goals and objectives.

5.3.4 Design Criteria

Design criteria are specific, *measurable* attributes of project components developed to meet project objectives[1] and are typically developed by the project implementation team as a means of clarifying project objectives. Design criteria are acceptable benchmarks for individual components of a design, providing numeric allowable limits of performance and tolerance. Criteria for habitat restoration and design define the spatial and temporal aspects of project objectives. They also address any constraints to fully achieving project objectives that may be imposed by social, political or jurisdictional boundaries.

Ideally, design criteria are developed with stakeholder review and feedback, such that they clearly represent the intent of the project and identify the risk associated with various design components. Perhaps equally important, design criteria provide a framework by which to measure project success. Design criteria can provide the ideal framework for establishment of a monitoring plan that is directly related to design objectives and is capable of evaluating the success of a project. (For further discussion of evaluation criteria to measure success, refer to Kondolf and Micheli[2].)

5.3.4.1 Examples of Design Criteria

Design criteria for stream habitat restoration and design can be categorized relative to the process they are intended to define or the objective they are intended to meet. For example, the following attributes can be defined using design criteria:

- Channel form: Design criteria define whether the channel location is allowed to deform over time, the degree to which it is allowed to migrate within a defined corridor, and what channel pattern (braided, meandering, or straight) will be applied.

- Floodplain function: Design criteria define the frequency, timing, and duration of floodplain inundation as it relates to stream stability, riparian vegetation composition and health, and fish and wildlife habitat development and connectivity.

- Aquatic habitat: Design criteria define what species or life stages are targeted, or what degree of habitat and species diversity is to be achieved.

- Timeframe: Design criteria define the timeframe during which objectives are to be met, and may specify both durability and longevity.

Design criteria for many project components of channel and stream habitat design can be related to hydrologic events, such as the design flood, dominant flow, high fish passage design flow, or low flow conditions. Projects requiring full channel restoration or reconstruction may require a suite of design discharges to adequately meet project objectives. A low-flow design discharge may be necessary to design certain habitat elements (such as pool depth); a high fish passage design flow will be necessary to ensure individual structures (such as culverts, fishways, and drop structures) provide unobstructed fish passage; a dominant-flow design discharge may be necessary to design channel components that relate to geomorphic function (such as cross-section and planform); and a flood level design discharge may be necessary to design certain habitat elements within the floodplain (such as off-channel habitat) and project components in the channel or floodplain that are expected to remain stable up to some maximum flood event.

There are two classes of design criteria – performance criteria and prescriptive criteria. Performance criteria define *what* a project will achieve and the duration of benefits, while prescriptive criteria define *how* the project will be undertaken. Performance criteria "describe the required performance or service characteristics of the finished product or system without specifying in detail the methods to be used in obtaining the desired end result"[3].
Examples of performance criteria include:
- Create spawning habitat for 10 additional pairs of spawners per given length of stream,
- Provide off-channel rearing habitat for 10,000 juvenile fish for 10 years, and
- Provide upstream passage for adult chum during all flows up to the high fish passage design flow.

Examples of prescriptive criteria that relate to the above performance criteria include:

- Create X square feet of spawning habitat per given length of stream
- Create X acres of off-channel rearing habitat
- Create X number of drop structures of 1-foot or less at all flows up to the high fish passage design flow.

The difference between the two types of design criteria can be illustrated by considering the project objective of increasing cover and spawning habitat by installing large wood in a channel. Performance criteria may include a target minimum volume of cover habitat and area of spawning habitat directly associated with large wood after a given period of time, without dictating how this will be achieved. Prescriptive criteria, on the other hand, may dictate the size, volume, number and location of large wood complexes, and the method of installation. While performance criteria may be better suited to ensuring that project objectives are achieved, they must be carefully articulated such that they are reasonable, achievable, and measurable.

5.3.4.2 How Design Criteria Relate to Monitoring

As described above, design criteria can be developed as either performance criteria or prescriptive criteria. Those developed as performance criteria can facilitate the development of a monitoring plan capable of measuring project performance relative to the established project goals and objectives. For example, performance criteria for a channel modification project intended, in part, to enhance salmonid spawning habitat may include the expectation that a minimum number of redds will be established by a specified species over a specified timeframe. Monitoring plans to evaluate these performance criteria will include redd counts and will document species and timeframe. Monitoring plan and protocol development is further discussed in the *Monitoring Considerations* appendix.

Prescriptive criteria can also be used as the basis of a monitoring plan, though such monitoring is better suited to evaluating durability and longevity of design components rather than success of meeting overall project goals and objectives. Post-implementation monitoring based on prescriptive design criteria entails measuring physical attributes of an implemented project, rather than its outcome. For example, prescriptive criteria may dictate the number of pieces of large wood placed and the period of time over which they are expected to perform. (In contrast, performance criteria associated with large wood may specify fish use of habitat created by the wood.) To evaluate the success of a project relative to these prescriptive criteria, a monitoring plan must include a count of the number of pieces of large wood installed at the end of the prescribed time period. By comparing post-project measurements to pre-project prescriptive design criteria, the success of individual project components can be evaluated (e.g., that the structure withstood the 50-year design flood event and still persists). But only performance criteria can be used to determine if the project objectives related to fish usage of habitat created by the structure were achieved.

Consider again the example of project objectives including improved aquatic habitat through increased numbers of log jams. With prescriptive criteria dictating the form and number of log jams, a project may be deemed unsuccessful if the jams became dislodged before the end of the intended project life. Yet the jams may reform in another location, with the same wood, in the same reach and continue to provide desired function. Thus, monitoring conducted using a plan that is based on performance criteria may indicate project success; while monitoring conducted using a plan based on prescriptive criteria may indicate a failed project, even though project objectives (increased habitat associated with log jams) were achieved.

5.3.5 Levels of Design

Project design typically occurs in a number of phases, including conceptual design, detailed design, and development of plans and specifications. Conceptual designs are commonly presented to identify and illustrate select alternatives and to identify project components. They often include schematics of each alternative, with basic design considerations to address project feasibility. This level of design provides a platform for the project owner, project designer, and other stakeholders to review project components at an early stage, and to develop consensus on an implementation approach. A selected concept will then be carried forward to identify all necessary design components and to develop design criteria for these components. Development of conceptual designs typically requires thorough assessment, topographic information, analysis of hydrology, as well as basic hydraulic evaluation to establish feasibility of selected alternatives.

The design process that follows typically requires detailed analysis to develop designs that address all established criteria. The required level of analysis in design will depend greatly upon the technique selected, site conditions, project goals and objectives, and the acceptable level of risk. Regardless of the level of analysis conducted during the design process, the designs should be sufficient to ensure that the established criteria can be met.

Plans and specifications represent the end product of the design process. The amount of information and detail provided in the plans and specifications should reflect the level of design analysis, the risks associated with project implementation, and the objectives of the project. For example, a project involving the installation of large wood to address a deficiency of wood in a remote stream may include typical installation guidelines (e.g., obstruct 30 to 50% of the bankfull channel, stabilize the logs by burying 1/3 of their length, interlocking the logs, or pinning them between two or more live trees on the bank), and specify the number and general location of large wood complexes (e.g., along the outside bank of meander bends) and the number of pieces of wood within each complex, but ultimately rely on the experience and judgment of the construction crew or supervisor to select the specific location and orientation of each individual log and the installation methods. Alternatively, a large log jam structure placed in close proximity to critical infrastructure (e.g., upstream of a bridge) that is intended to protect a streambank in addition to providing related habitat may require detailed plans and specifications that illustrate the placement and orientation of each piece of the structure, anchoring methods, depth of installation, and other design details.

The contracting mechanism and nature of the project will also dictate the necessary level of detail in plans and specifications, or vice versa. A contracting mechanism that solicits lump sum bids for completed project elements will require substantial detail in plans and specifications, while a contracting mechanism that solicits time and materials unit cost bids may allow for lesser detail in plans, and rely on the construction supervisor to implement according to his/her judgment.

5.4 References

[1] Miller, D. E. and P. B. Skidmore. 2003. A foundation for establishing a standard of practice for natural channel design. *In*: Montgomery, D. R., S. M. Bolton, D. B. Booth, and L. Wall (editors). Restoration of Puget Sound Rivers. University of Washington Press, Seattle, Washington.

[2] Kondolf, G. M. and E. R. Micheli. 1995. Evaluating stream restoration projects. Environmental Management 19(1): 1-15.

[3] Clough, R. H. 1986. Construction Contracting, Fifth Edition. John Wiley & Sons, New York, New York.